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Clinical and Chemical Observations
on Plumbism,
DUE TO LEAD-POLLUTED WATER;

WITH HINTS ON ITS PREVENTION :

BY

JOHN BROWN, M.D.,

B.S., D.Sci. Vict., L.R.C.P., Lond., &c.,

Gold Medallist in Clinical Medicine and Surgery, Charing Cross Hospital ;

Physician to the Sourhall Fever Hospital ;

Medical Officer of Health for the Borough of Bacup.

THESIS PRESENTED FOR THE DOCTORATE IN MEDICINE IN THE VICTORIA
UNIVERSITY, OCTOBER, 1889.

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CLINICAL AND CHEMICAL OBSERVATIONS

ON

PLUMBISM.

BY JOHN BROWN, M.B., D. SAN. SCI. VICT.,

Gold Medallist in Clinical Medicine and Surgery, Charing Cross Hospital.



THE subject chosen for this thesis is one which has attracted considerable attention from the Medical Profession.

Importance
of Plumbism.

Medical Officers of Health, whose mission is to prevent disease, have taken deep interest in this subject. In the Public Medicine Section of the British Medical Association recently held at Leeds, an important discussion was introduced by DR. SINCLAIR WHITE on "Contamination of Drinking Water: its Causes and Prevention." During the past few years, there have been several severe outbreaks of plumbism in the North of England—especially in Lancashire and Yorkshire; very few towns have escaped where the public water supply is largely dependant upon the rainfall. The town in which I practise has had a severe epidemic during the past two years. Cases have occurred before that period, but not to such an alarming extent. For the space of three years I have been taking notes on plumbism due to polluted water. The field of research, lying within the district where I practise, offers abundant scope for enquiry, and has enabled me to watch many phases of plumbism scarcely possible to Physicians in Hospital practice. Some patients have been under my care about three years, during which period I have had 500 cases under observation, and have taken notes on over 400 of these. In addition to my own locality, I have visited cases in Workhouses, in the London Hospitals, and Manchester Royal Infirmary.

I must express my sincere thanks to DRs. MORGAN, LEECH, DRESCHFELD, ROSS, STEEL, and others, of the Manchester Infirmary staff, for their extreme kindness in allowing me to make use of their cases, instruments, &c, in connection with my investigations, and for their valuable hints and suggestions.

Insidious
Nature.

There is no form of disease more insidious, ubiquitous and manifold in its manifestations, and which so closely simulates other diseases as plumbism. If time and space allowed, scores of cases could be cited in which it has been treated for rheumatism, gout, indigestion, cephalalgia, epilepsy, meningitis, cerebro-spinal-meningitis, &c., &c. Reading the past in the light of the knowledge obtained by the recent researches made in regard to it, I believe many have died of so called meningitis, cerebro-spinal-meningitis, encephalitis, and epilepsy, which, if traced to their true cause, were really due to lead polluted water. In Bacup, and other large towns, I have found that plumbism had so simulated other diseases, that it had not been recognised even by careful and pains-taking physicians. The study, however, which I have made of this subject, and the chemical researches which I have recently carried out in my own and other laboratories, lead me to hope that I may be able to elucidate some points which may help in the diagnosis of obscure cases.

Diagnosis.

The diagnosis of the cases has been carefully made; doubtful ones have been eliminated. In many, the drinking water has been examined, and lead in poisonous quantities found. In 55 cases I made quantitative analyses, and the average amount of lead was 0.66 grain, or $\frac{2}{3}$ gr. of lead per gallon. The quantity varied from $\frac{1}{10}$ gr. to 2.2 gr. per gallon.

Mortality.

There were 7 deaths due to plumbism in 1888, 3 males and 4 females, all adults. As there were 500 cases observed, this gives a death-rate of 1.4 per cent. All died with epileptiform convulsions. Their ages were as follows: 18, 20, 21, 23, 45, 48, and 54 years.

Conditions which influence plumbism:—

The following table gives the ages at which the cases occurred. Age.

Under 5 years	...	5
5 and under 10	...	23
10 ,, 15	...	28
15 ,, 25	...	92
25 ,, 50	...	201
50 and upwards	.	55
		<hr/> 404

The table shows that the extremes of life are less predisposed to plumbism than from 15 to 50 years of age. There were 56 cases under 15 years of age, but only two really serious. One was a girl aged 4 years, in whom it simulated infantile paralysis, to which I shall refer later; and the other a girl aged 12, who had drop-wrist, epilepsy, &c. The more common symptoms of plumbism in children are the blue line, colic, anæmia, and the absence of the patellar tendon reflex. Of those 50 years and upwards there were only 5 serious cases. The toxic influence of lead seems to have little effect on the nerve centres after that age. In one house where there were 3 cases of saturnine epilepsy, of whom 2 died; the mother, aged 60 years, had no serious symptoms whatever.

There were 153 males and 251 females, showing females Sex. to be more predisposed to plumbism than males. This might be expected from females being weaker, and their nerve centres more susceptible to toxic influences, such as alcohol, opium, &c. As both sexes were exposed to the same conditions and drank the same lead-polluted water, the evidence proves that the female sex is greatly predisposed to plumbism, and particularly to the epileptic type. In 24 cases of epilepsy there were 17 females.

Most of the severe cases, especially of the epileptiform type, Season. occurring in the months of February, March and April, the spring

season, is probably favourable to this form of plumbism. Four deaths occurred during these months—3 females and 1 male.

Constitution. Constitutional susceptibility is an important factor. Persons who are feeble, nervous, or convalescent from recent illness, are predisposed to the influence of lead. Some families are peculiarly liable; in one, for instance, three sisters were suffering from severe plumbism, whilst the remaining members escaped. Other families subjected to the same conditions, had no serious symptoms, but the blue line and slight gastric disturbances were present.

Alcohol The evidence in favour of the predisposition to plumbism, by persons addicted to alcohol, is most convincing. There were 21 cases of paralysis of the extensors of the wrist, of these, 12 were alcoholics, 3 doubtful, 6 non-alcoholics. Alcoholism has also an important bearing on prognosis, recovery being much longer, and in some cases the cure is never complete.

Previous Attacks. Having once suffered from plumbism, there is a predisposition to early relapse, if lead-polluted water be again taken. A patient who came out of the Manchester Royal Infirmary with the blue line gone, soon began to suffer again, the blue line returning in a few weeks after drinking the lead polluted water.

Sanitation, &c. About 70 per cent. of the cases were amongst the poor and lower class of mill operatives, whose sanitary surroundings induce lower vitality. The majority of the worst cases occurred in families who had no filter. In the better class houses supplied with the same water, where filters were used, it was exceptional to meet with any severe case of plumbism.

Observations on some of the symptoms of Plumbism.

Symptoms. *Colic.*—This is one of the commonest and earliest symptoms of the disease, and was present in 206 cases.

Dyspepsia.—Nausea, vomiting, anorexia, foul breath, and indigestion, are early symptoms. They may be due to lead acting as an irritant on the alimentary canal, and partially arresting the secretions of the stomach and intestines.

Anæmia and Cachexia.—In 148 cases the anæmia and cachexia were marked.

Headache is an early and common symptom. It was present in 197 cases. Of these, 175 were frontal, 13 vertical, 8 occipital, and 1 temporal.

Blue Line in the gums was present in 339 cases.

Blue Patches were present on the mucous membrane of the cheeks and lips in 36 cases. The *Blue Patches* on the mucous membrane in every case were immediately opposite heavy deposits of tartar on the teeth, which proves that this is the cause of their formation.

The *Blue Line* on the gums appears to be continuous, but on microscopical examination it will be found to be otherwise. I have prepared specimens in which it will be seen that the sulphide of lead is deposited in small round patches, each distinct from its fellow, as described by DR. HILTON FAGGE.¹

It is generally supposed that the blue line on the gums is caused by the liberation of sulphur from its combination in albuminous foods by the action of saprophytes, the sulphur then combining with the lead, and being deposited in the capillary wall of the papillæ of the gums. As the proteids only contain 0.3 per cent. of sulphur, whilst sulphocyanide of potassium, which is constantly present in the saliva in the early stages of plumbism, contains 37 per cent., the question naturally arises whether the latter is not the true source of the sulphur which causes the blue line. I found by experiment, that the sulphur was easily liberated from the sulphocyanide of potassium, contained in the

saliva by nascent hydrogen. The experiment was done in the following way: A quantity of saliva was placed in a test tube, and dilute sulphuric acid and a small piece of zinc along with it. Nascent hydrogen was first liberated, and afterwards sulphuretted hydrogen was formed. The presence of sulphuretted hydrogen was conclusively shown by the smell, and the effect on a piece of bibulous paper soaked in a solution of acetate of lead. This experiment proves that free hydrogen liberates sufficient sulphur to form a sulphide in the presence of lead, and it is an established fact, that hydrogen is largely given off in butyric, and other fermentations which may occur in the mouth. I am inclined to think that the blue line in the gums is more probably due to this cause than to the sulphur in the food.

Patellar tendon reflex. This was tested in 196 cases, with the following results:

„	„	„	Absent in 71.
„	„	„	Present in 79.
„	„	„	Absent on one side, the other normal, 5.
„	„	„	Absent on one side, and feeble on the other, 7.
„	„	„	Absent on one side, and excessive on the other, 1.
„	„	„	Feeble, 15.
„	„	„	Excessive, 15.

Abnormality of the patellar tendon reflex is an early symptom of plumbism, and it is useful in diagnosis and prognosis. It was absent in 71 cases.

Knee Jerk.

The absence of the knee jerk is probably due to the toxic and inhibitory effect of lead on the nerve centres in the spinal cord, in support of which the following may be cited.

This year I have examined the following cases, in which the knee jerk has been absent on both sides, due probably to toxic influences of morbid products of bacterial origin and

other poisons. In these, as in lead, the knee jerk generally returns after recovery.

Croup or Diphtheria	8 cases	knee jerk absent.
Scarlet Fever	8	" " "
Typhoid Fever	5	" " "
Carbonic Oxide poisoning	1	" " "
Diabetes	4	" " "
Tobacco	4	" " "

There are several interesting features to be observed. The knee jerk is often excessive, showing irritation of nerve centres; and afterwards it becomes feeble, then disappears. It is occasionally unilaterally absent, a fact which I have never observed in any other disease. Dr. BUZZARD² records one case of plumbism where the knee joint was absent on one side. It is valuable as an aid to prognosis, its return being an indication that the lead is being eliminated. The knee jerk often returns in a few weeks; in severe cases, it may be absent as long as six months. In some cases of lead paralysis, it has not returned after 12 months, possibly through organic changes of the motor nerve cells in the cord.

In a few cases I have observed an expression of countenance, which I believe to be peculiar to plumbism. In addition to the cachexia, there is a lack of expression, mental vacuity, cheeks are full, and resembles myxœdema, but differs in that there is no redness of the cheeks.

Faciei
Saturni

Plumbism simulates various forms of rheumatism, and is frequently mistaken for that disease. One patient was treated during several weeks for muscular rheumatism, and the true cause was not diagnosed until saturnine tremors and drop-wrist developed. Lumbago, and pains in the muscles of the arms and legs occur.

Rheumatism.

Articular rheumatism is simulated very closely, but it is easily diagnosed. The pulse is slowed, urine paler, specific gravity lower, urea much less than normal, sweat less.

In rheumatism, the urine is high coloured, urea is in excess, deposits of urates occur, and specific gravity is higher. In rheumatism, the sweat is increased and acid. In plumbism, the sulphocyanide is often absent from the saliva. In rheumatism, it is usually present, and above the average, and the saliva is acid in reaction.

Myalgia. Shooting pains in the extensors of the hands, arms, back, also in the legs, were very common, and usually mistaken for muscular rheumatism.

Saturnine Gout. S.H., aged 44 years, had gout several times in the great toe. It was not diagnosed for some time. It was associated generally with severe colic, constipation and rheumatism in the knee joints. There were tophi in the ear. It differs from ordinary gout by the history of the case and its association with well marked symptoms of chronic plumbism. The blue line on the gums, and the supply of lead polluted water assist the diagnosis. In this case I blistered the knee joint, and analysed the serum so obtained: 1 c.c. gave 2 c.c. by volume of nitrogen. The specific gravity being 1008. SIR DYCE DUCKWORTH,³ in St. Bart's. Hospital Gazette, gives an excellent article on saturnine gout.

Saturnine Sterility. Plumbism is a cause of sterility. It lowers the general vitality and virility of both sexes. The evidence is not so strong in the male, but in the female there can be no doubt of it. It is the cause of amenorrhœa, which is not uncommon.

Amenorrhœa. DR. JOHNSON⁴ observes that this is an early symptom in plumbism. Several cases were cured by pure water supply, and treatment.

Abortions. There were 7 cases of abortion. DR. BAKER⁵ and others have also drawn attention to this.

Saturnine Nephritis. Plumbism causes albuminuria, especially in cases of colic. The irritant action of lead and the increased vascular tension ultimately produce organic changes in the kidney, resulting in chronic nephritis. In two cases, which were under observation for several years, I found no evidence of acute nephritis. Both had been drinking lead-polluted water for years, and it was only within the last eighteen months that I found it out.

Influence of Lead on the Secretions and Excretions.

In the alimentary canal it causes lessened secretion, dryness of the mouth, anorexia, and constipation.

Salivary secretion. Lead caused increase of the saliva in one case only; as a rule there was diminished secretion, with dryness of the mouth.

Salivary
Secretions.

I carried out over 90 experiments on the presence of sulphocyanide in the saliva, as an aid to prognosis and diagnosis. The results go to confirm DR. FENWICK'S views that the sulphocyanide has a close relationship with the functional activity of the liver, and that it is probably derived from the biliary salts. In 23 experiments on cases of plumbism I tested for sulphocyanide, the method I employed was a modification of DR. FENWICK'S colour test, as described in his work on "Saliva." My standard colour was made as follows: Several experiments were made with my own saliva, the sulphocyanide being converted into the sulphocyanide of iron. The normal average was then taken, and called 4 units of colour. A standard solution was made with sulphocyanide of ammonium and ferric chloride to match; in some cases the colouration was obscured by the presence of blood, &c. The following method was found to produce accurate results. Take 2 c.c. of saliva, convert into the sulphocyanide of iron as described by DR. FENWICK, and now add drop by drop from a graduated burette a standard solution of perchloride of mercury. Having standard solutions of sulphocyanide of potassium, ferric chloride, and perchloride of mercury, the amount of sulphocyanide can be given with infinitesimal exactness.

The following are the results of the 23 experiments:—

In 7 cases the colour was absent

„ 8 „ there was 1 unit of colour

„ 5 „ there were 2 units of colour

„ 1 „ „ 3 units of colour

In 1 case there were 4 units of colour, normal

„ 1 „ „ 6 units

The absence or presence of the sulphocyanide in the saliva from experiments I made on starch does not show any appreciable difference in its power of converting starch into sugar. Does urea exist in the saliva? In Ziemssen, Vol. XV. fol. 414, it is stated that urea may occur in cases of plumbism. I have failed to get the slightest trace of urea by means of the hypobromite method. If only 4 drops of urine were added to the saliva, nitrogen was at once set free.

Gastric
Secretions.

Gastric Secretion.—The gastric juice is probably lessened in quantity. The secretion of the intestines is lessened, constipation being the result of its partial arrest, as well as spasmodic contraction of the intestines, due to colic, and also to less secretion of bile.

Biliary
Secretion.

That the biliary secretion is lessened is pretty certainly shown by the following facts :—The motions are dry, constipation is present, there is less urea and urochrome in the urine, less sulphocyanide in saliva, due to the lessened biliary salts.

Excretions.
Sweat.

Sweat.—In nearly every case the perspiration is lessened. In only one was there marked increased perspiration, viz : in a man suffering from phthisis. In chronic cases the skin is abnormally dry. Diaphoresis is most difficult to produce. In a case of saturnine nephritis, pilocarpine used hypodermically was the only remedy that was successful.

Fæces.

Obstinate constipation was present in 148 cases. The fæces were hard and dry, and showed deficiency of bile.

Urine.

Urine—The most marked effects produced are found in the specific gravity, colour, amount of urea excreted, and the production of albuminuria. DR. OLIVER⁶ states that he always found the urea decreased in plumbism.

In the analysis of the urine it was difficult, and in most cases impossible to get all the urine passed within 24 hours. In

order to get tolerably accurate results, I adopted the method of taking a sample of the urine passed during the night, and making comparative experiments with healthy urine under like conditions. In 125 analyses the evidence was conclusive that there was less specific gravity, less urochrome, lessened excretion of urea, and in some cases albuminuria. Fallacies may arise by this method, because in cases where the amount of urine passed is small during the night, specific gravity, urochrome, and urea, may be in excess. If, however, the amount of urine passed be taken, it will be found that these products are all less in the aggregate.

The colour of the urine may be examined by the adoption of VOGEL's system. Lately, I have succeeded in making standard test papers and solutions, which will give the colourations to decimal points with exactness.

Urochrome is derived from the hæmoglobin, and is the result of its disintegration by the liver. The urochrome is less because of the saturnine anæmia, and consequent diminished functional activity of the liver.

Urea is lessened probably from the same cause, and also from functional derangement of the renal cells.

Albuminuria occurs in many cases, apart from organic changes in the kidney. In some, more particularly those of severe colic, a little albumen was present, no doubt due to increased arterial tension. This kind of albuminuria generally passes away, but it may be the forerunner of saturnine nephritis. OLLIVIER⁷ states that albuminuria is common in plumbism.

Albumen.

Remarks on the method used for the estimation of Urea.

I used freshly prepared hypobromite of soda. I carefully observed the atmospheric pressure and temperature. In 100 analyses I took 1 c.c. of the urine and measured the volume of nitrogen gas set free. I found that 1 grain of pure urea pro-

duced 26 c.c. of N. at 29.30 inches, T. 63° from this the data for the estimation of urea per cubic centimetre of urine could be calculated.

The following table shows the Volume of nitrogen produced by 1 c.c. of urine from 10 healthy persons and 10 suffering from plumbism.

Urine from 10 healthy persons.

Sp. Gr.	Volumes of Nitrogen.
1018	7.5 c.c. of N.
1025	13.2 "
1022	6.6 "
1025	10.0 "
1018	9.0 "
1022	9.9 "
1030	11.8 "
1020	9.7 "
1028	16.0 "
1025	13.0 "
<hr/> Total 10233	<hr/> 106.7 "

Average Sp. Gr. 1023. Average volumes of Nitrogen from 1 c.c. of urine = 10.6 c.c. of Nitrogen.

Urine from 10 cases of Plumbism.

Sp. Gr.	Volumes of Nitrogen.
1020	8.3 c.c. of N.
1018	6.9 "
1010	6.4 "
1006	3.5 "
1025	4.5 "
1022	5.2 "
1017	10.1 "
1012	6.1 "
1013	4.8 "
1018	6.9 "
<hr/> Total 10161	<hr/> 62.7 "

Average Sp. Gr. = 1016. Average volume of Nitrogen for 1 c.c. of urine = 6.2 c.c. of Nitrogen.

There is therefore considerably less specific gravity, and also less urea.

The relative value of the specific gravity and colour in estimating amount of urea is interesting, and, speaking broadly, the specific gravity is the safer guide. The exceptions can be explained by age, disease, &c.

Anæmia.—This is an early and common symptom, it was well marked in 148 cases; it occurs at all ages. In some cases it is likely to be confounded with progressive pernicious anæmia. One patient in whom I had diagnosed pernicious anæmia, I found it was due to lead, the drinking water containing $\frac{1}{2}$ gr. per gallon; her husband was suffering from plumbism. The etiology is important, as the cure is dependent thereon. Anæmia.

The cause of the anæmia may be (*a*) disturbance of the functions of digestion and assimilation; (*b*) disturbance of the excretions of the skin, bowels and kidneys, and consequently retention of morbid products; (*c*) lessened blood formation. Etiology.

Influence on the circulation.—The heart's action is increased in force and slowed. CURCI⁸ believes that lead slows the heart's action by its toxic influence on the vagus. The pulse tension is increased, and pulse-rate decreased from 10 to 20 beats per minute. A low pulse-rate is very common; occasionally the pulse-rate is increased. The state of the pulse as to tension and rate assist prognosis. Blood.

Microscopical.—There is great diminution of red blood cells, and increase of the white cells, the rouleaux are not so perfectly formed, and poikilocytes, microcytes and blood-plaques are present. When stained with methyl-violet, the giant cells take up the colouring matter well. Some had one or two nuclei, and one three nuclei. State of the Blood.

In marked anæmia, the red corpuscles are enormously reduced, and the white greatly increased. The following table Number of Blood Corpuscles.

gives the number of red and white corpuscles in $\frac{1}{100}$ m.m.

(a) 106 red corpuscles	(a) 18 white corpuscles
(b) 144 " "	
(c) 115 " "	
(d) 186 " "	(d) 20 " "
(e) 429 " "	(e) 24 " "
(f) 209 " "	(f) 32 " "

Amount of
Hæmoglobin.

Testing by the hæmoglobinometer is a much easier way of ascertaining the state of the blood in saturnine anæmia, than by the hæmocytometer, the results being more certain and reliable. The amount of hæmoglobin in one case was 52 per cent. below the normal, and the white corpuscles were greatly increased.

The results obtained by means of the hæmocytometer are unsatisfactory. In (a) and (b) the same specimen of blood was used, yet there is a difference of about 40 per cent. in the number of red corpuscles. In (d) and (e) the blood was from the same patient, with an interval of two days between the examinations, and here the difference in the number of red corpuscles is over 100 per cent.

Urea in
Blood.

Blood-serum in plumbism. BABBINGTON⁹ states that in plumbism the blood-serum contains 1·5 per cent. of urea, whilst HOPPE-SEYLER¹⁰ only gives 0·127 per cent. of urea. My experiments show that BABBINGTON is more likely to be correct. In one case of plumbism the blood-serum contained 1·4 per cent.; and in a case of rheumatism I found the same per centage.

Influence of Lead on the Nervous System.

SATURNINE NEUROSES.

There were 24 cases of epilepsy: 23 were of the Haut Mal variety, and 1 Petit Mal. None of the attacks began with the "cry." Several had an aura, usually beginning in the legs or hands.

Saturnine epilepsy is diagnosed from true epilepsy by the absence of family history of epilepsy. It is rare for faces or urine to be voided. In only one case was the tongue bitten. The patients have the anæmia and cachexia of plumbism. The urine, if examined, will be found to contain less urea than normal. DR. SIEVEKING¹¹ says, 'that in true epilepsy there is excess of urea. The history of the case and other symptoms of plumbism will assist the diagnosis. In some cases, epilepsy was an early symptom, especially in young persons, 4 of whom died. The diagnosis of plumbism was not made for some months after death. The circumstances connected therewith will be referred to later on.

Saturnine
Epilepsy.

Table of 24 cases of epilepsy and convulsions, stating sex and age.

	Name	Sex	Age
1.	J.B. ...	F. ...	55 yrs.
2.	F.B. ...	F. ...	35 "
3.	W.B. ...	F. ...	28 "
4.	J.G. ...	F. ...	28 "
5.	L.H. ...	F. ...	23 "
6.	J.J. ...	M. ...	26 "
7.	F.R. ...	M. ...	54 "
8.	T.V. ...	F. ...	36 "
9.	J.W. ...	M. ...	48 "
10.	G.M. ...	F. ...	42 "
11.	J.L. ...	F. ...	42 "
12.	W.S. ...	F. ...	25 "
13.	J.D. ...	M. ...	40 "
14.	J.F. ...	F. ...	23 "
15.	J.R. ...	F. ...	45 "
16.	J.H. ...	F. ...	39 "
17.	J.B. ...	F. ...	32 "
18.	H.J. ...	M. ...	38 "
19.	J.M. ...	M. ...	23 "
20.	A.K. ...	F. ...	18 "
21.	B.R. ...	M. ...	21 "
22.	C.K. ...	F. ...	20 "
23.	C.S. ...	F. ...	23 "
24.	A.S. ...	F. ...	20 "



As there were 7 males and 17 females, this proves that females are predisposed to epileptic convulsions in plumbism: 50 per cent. of the cases were between the ages of 18 and 30, which shows there is a great predisposition to saturnine epilepsy at this period.

Headache.

Headache was an early symptom, and was present in 197 cases; of these 175 were frontal. Frontal headache may be due to (a) irritation of the stomach and alimentary canal (DR. HUGHLINGS JACKSON¹² states that frontal headache is usually of abdominal origin); (b) irritation of the vagus (as stated by DR. ROSS¹³); (c) or to anæmia, which is so common; (d) or retention of urea and other morbid products. In ordinary uræmia, frontal headache is very common.

Saturnine Paralysis.

The most common form is the drop-wrist. There were 21 cases, males 11, females 10, ages from 26 to 53 years, with the exception of one aged 12. Paralysis is a late symptom; it was preceded in nearly every case by tremors of the hand, afterwards by paresis, and then paralysis. In no case did I find the supinator longus paralysed. The cause of the wrist-drop has been attributed to peripheral neuritis. The symptoms are equally well explained by attributing it to the inhibitory action of lead on the motor nerve cells in the anterior cornua of the spinal cord. Certain changes have been found in the musculo-spiral nerve which have been described as neuritis. These changes are probably secondary to toxic or organic changes in the anterior cornua. The tremors of the muscles, paresis and paralysis are so many changes involved in the toxic influence of lead on the nerve cells. Very few sensory symptoms are complained of, usually a little coldness in the fingers, often beginning in the fourth and fifth fingers. As the motor fibres of the nerves are not used, degenerative changes take place in the muscles and also in the nerve, due to disuse. Lead has great affinity for albumen and protoplasm. It most likely combines and forms a definite compound with the protoplasm of the nerve cells; this would seem to interfere with the

function of the nerve cells, and in time to produce degenerative changes. If they were inflammatory changes, the probability is that the damage to the nerve centres and muscles would be permanent. The prognosis in drop-wrist is favourable, if not of too long standing, and the patient is a non-alcoholic.

Several of the cases I have observed, have recovered the use of the hand in from 6 to 12 months. Some never perfectly recover the use of the muscles. The last to recover are the extensors of the fourth and fifth fingers.

The first interossei were wasted in a few cases, and the thenar eminence also in two cases of drop-wrist. Only 3 of the cases completely recovered. In 4 almost complete recovery occurred. The others presented only slight improvement. The earliest recovery is not effected sooner than from 6 to 15 months.

The following table gives a summary of the 21 cases of drop-wrist.

	Name	Age	Sex	Alcoholic	Result
1.	J.A. ...	35 yrs. ...	M. ...	Yes ...	only partial recovery.
2.	J.B. ...	55 " ...	F. ...	Yes ...	cure.
3.	J.B. ...	48 " ...	M. ...	Yes ...	only partial recovery.
4.	W.G. ...	35 " ...	M. ...	Yes ...	" "
5.	J.G. ...	28 " ...	F. ...	No ...	" "
6.	J.J. ...	26 " ...	M. ...	Yes ...	" "
7.	G.K. ...	47 " ...	M. ...	No ...	" "
8.	W.L. ...	40 " ...	M. ...	? ...	cured.
9.	J.M. ...	53 " ...	M. ...	Yes ...	complete recovery.
10.	F.W. ...	48 " ...	M. ...	Yes ...	died.
11.	T.H. ...	39 " ...	M. ...	Yes ...	slight improvement.
12.	J.H. ...	46 " ...	F. ...	? ...	" "
13.	P.H. ...	41 " ...	F. ...	No ...	" "
14.	F.G. ...	39 " ...	F. ...	No ...	" "
15.	J.B. ...	32 " ...	F. ...	? ...	nearly well.
16.	J.R. ...	52 " ...	F. ...	No ...	only slight improvement.
17.	F.R. ...	12 " ...	F. ...	No ...	cured.
18.	J.W. ...	38 " ...	M. ...	Yes ...	no improvement.
19.	F.B. ...	44 " ...	F. ...	Yes ...	only partial recovery.
20.	W.C. ...	31 " ...	M. ...	Yes ...	partial recovery.
21.	J.C. ...	34 " ...	F. ...	Yes ...	" "

Infantile
Paralysis.

One case, a child nearly 4 years of age, had paralysis of both legs. She began with tremors paresis and paralysis. This child had the dark blue line on the gums, anæmia, frontal headache, and excessive knee jerk, colic, constipation, and painful micturition; it simulated anterior-polio-myelitis. The history and course of the disease showed that it was due to lead. The father and mother were affected at the same time, with well marked paralysis of the legs and arms, colic, and epileptic convulsions of saturnine type. The child recovered. BEATY¹⁴ has found a marked change in the internal and anterior group of nerve cells in the cervical and lumbar enlargements of the spinal cord. OPPENHEIM¹⁵ also describes sclerosis of these parts.

Spastic
Paralysis.

A patient aged 28 years, had all the symptoms of spastic paralysis. The prognosis was grave. The water supply on being analysed, was found to contain lead to the amount of $\frac{1}{2}$ grain per gallon. The patient, after spending some time in the Manchester Royal Infirmary, has gone to reside in another district, where he is improving in health, without the aid of medicine. Whilst in the infirmary the water supply was tested, and found to contain lead.

Saturnine
Insanity.

Several patients became mentally deranged, which may be described as forms of insanity due to the toxic influence of lead. They occurred in severe and chronic forms of plumbism. CLARKE¹⁶ records cases of insanity due to lead.

(1) Homicidal.—Mr. A. aged 35 years, threatened to kill his wife, became very suspicious, and for a time she had to leave him. His expression and mental obliquity were evident to all. He had lead paralysis, and was treated in Manchester Royal Infirmary, but has not recovered the use of his hands yet.

(2) Hallucinations.—Mrs. B., aged 53, had hallucinations, and did not know her husband. She suffered from epileptiform convulsions and paresis of both hands. There were three cases, all females; the hallucinations were of vision.

(3) Delirium and suicidal mania.—Mr. J., aged 28, had lead paralysis of both legs and arms, most severe colic, delirium, and tendency to suicide. The delirium closely simulated delirium tremens.

(4) Delusions.—Mrs. M., aged 38, had severe lead colic and delusions; did not know her own family.

(5) Saturnine General Paralysis.—Mr. J., aged 48 years, had symptoms which threatened to develop into general paralysis of the insane. Another medical man was called in later, and the patient was removed to a lunatic asylum. His wife had acute glaucoma due to lead. The water supply contained 1 gr. of lead to the gallon. MR. MOULD informs me that he was called in to a case diagnosed as general paralysis of the insane, which was traced to lead polluted water. The patient ultimately recovered.

(6) Saturnine Melancholia.—J.B., aged 38, had the blue line, anæmia, insomnia, epileptic fits, afterwards followed by religious melancholia. The water supply contained lead to the amount of $\frac{1}{2}$ gr. per gallon. The patient soon improved with change of air and pure water supply.

Saturnine meningitis

Meningitis.

"	"	Meningitis with epileptiform convulsions
"	"	Cerebro-spinal meningitis
"	"	" " Fever

In the month of May, there were two cases of lead paralysis in one house. The result of the inspection led to the discovery of a series of the most interesting cases of plumbism I have known. The facts are briefly as follows: two sisters, aged 41 and 43 years, had been suffering for nearly 18 months from plumbism. M.H. had paralysis of both hands, colic, &c. B.H. also had paralysis of both hands, colic and epileptiform convulsions. They had been treated at first for rheumatism, but recently they had been informed that they were suffering from lead poisoning. They reported that last year several deaths had

occurred from convulsions. I made inquiries, and found that four deaths took place within four weeks, in two houses, all at an age when lead acts most seriously on the nerve centres. The 4 deaths were certified by 3 different doctors, and were as follows: (1) B.K., female, aged 18 years, meningitis. (2) S.K., male, 21 years, meningitis with epileptiform convulsions. (3) A. A., aged 23 years, cerebro-spinal-fever. (4) C.A., aged 20, cerebro-spinal-meningitis. 1 and 2 were sister and brother; 3 and 4 were two sisters. These cases were not diagnosed as due to lead, until many months afterwards. From examination of the water supply, I found lead present in poisonous quantities. In these 3 houses there were within a few weeks, in the spring of last year, 4 deaths from convulsions. Two others suffered from the same complaint. One was removed and recovered; the other remained, and drop-wrist, &c., ensued. The other case was of a mild form.

In the year 1888 we had 18 deaths in Bacup from diseases in which convulsions are often well marked, occurring in persons between the ages of 9 and 55 years; of these, two were certified as chronic plumbism, and the 4 above were, no doubt, due to the same cause.

Locomotor
Ataxy.

The absence of patellar tendon reflex, has, until recently, been considered as pathognomonic of locomotor ataxy. There were 71 cases with the knee jerk absent, also a few with numbness, slight ataxy, neuralgia, pains in the muscles, and gastric disturbances; but the simulation in no case was likely to lead to error in diagnosis. PUTNAM¹⁷ records cases of pseudo-tabes due to lead.

Progressive
Muscular
Atrophy.

J.B., female, aged 44 years, had fibrillar tremors and wasting of the muscles of the fore arm, atrophy of the thenar muscles, also of the first interossei on both sides, and drop-wrist. The case has improved under treatment, and the drop-wrist partially recovered from. WILKS¹⁸ observes that progressive muscular atrophy may be due to lead.

The only case of ptosis I have seen which could be traced to lead, was under the care of DR. BUZZARD in the hospital for epilepsy, Queen Square, London ; as DR. BUZZARD intends to publish the case in "Brain," I forbear making further observations thereon.

Ptosis.

There were two cases of paraplegia, both of which recovered ; both had the blue line, colic, &c., well marked. MIRNOT¹⁹ observes that lead is a cause of paraplegia.

Paraplegia.

There was one case of pseudo-bulbar paralysis—J.A., aged 23 years, had slowness in protrusion of the tongue, difficulty in speaking, no difficulty in swallowing, was unable to read aloud, her voice was shaky, was unable to sing, but had no tremors of the tongue. The symptoms pointed to functional ataxy of the tongue, due to the toxic influence of lead upon the hypoglossal centre. She also suffered from epilepsy. Upon the 20th of September of this year, I found her impediment of speech much improved, but not right. Her sister, aged 22 years, had also a peculiar slow, stuttering speech, and other well marked symptoms due to plumbism ; when examined upon the 20th of September, she had recovered the power of speech.

Pseudo-bulbar Paralysis.

Insomnia is not an uncommon symptom, it was complained of by several.

Insomnia.

J.K., aged 55 years, a reporter, suffered from Scrivener's palsy, had the blue line on his gums. The water supply was lead polluted. He began to complain of fatigue in the hand, and of being unable to write, owing to irregular movements of the fingers and thumb ; ultimately he had to employ an amanuensis. Under treatment with pot. iodide and rest, he recovered. GOWERS²⁰ gives plumbism as a cause of writer's cramp.

Scrivener's Palsy.

Hyperæsthesia is a rare symptom usually occurring in chronic cases. Anæsthesia is also uncommon. Vertigo is not uncommon, especially in saturnine epilepsy ; sense of heat and burning are rare, usually occurring in the soles of the feet. The sense

Sensory Symptoms.

Chemical researches on cause, &c., of the Epidemic of Plumbism at Bacup.

Cause of the
Epidemic.

Many cases of lead-poisoning occurred, and it was suggested that they might have been due to the use of lead paints, &c., but the ages, occupations, and mode of onset precluded these causes. The water was inspected, and was examined by me many times, both the public and private water supplies, and was found to contain lead in dangerous quantities. The quantity varied from $\frac{1}{10}$ to over 2 grs. per gallon. Most of the cases were associated with the water supply from the Rossendale Waterworks Company. It is a remarkable fact, that there has been no outbreak of plumbism in connection with the Rossendale Waterworks water since its formation, thirty-five years ago. I know persons who have used this water for over thirty years and with no evil effects; but it should be observed that these people have taken the precaution to filter the water, which is a most important point. I have known persons using water from the same lead service pipes not filtered, to be attacked with acute lead poisoning in three weeks. Samples of this water have given $1\frac{1}{2}$ gr. per gallon. In the summer of 1887, there was a severe drought, and the Rossendale Waterworks reservoir was empty for a few weeks, also many of the private supplies failed. During this period, the incrustations on the lead pipes became dry and fell off, so that there was a free surface of lead exposed to the action of the water.

Action of the
Water on
Lead Pipes.

It is well known that very soft, pure, highly oxygenated water acts readily as a solvent of lead, also water polluted with sewage which contains nitrites, nitrates, and chlorides; whilst hard water containing carbonates, sulphates, phosphates, and silicates, does not act so freely. Lead in poisonous quantities was found in connection with the Rossendale Waterworks. Private supplies which had been polluted with sewage dissolved lead freely. Water with fifteen degrees of hardness from the millstone grit also contained $\frac{1}{2}$ gr. lead per gallon. The Waterworks Company collect their water from the moor, and their supply

is dependent almost entirely on the rainfall. The water has only $2\frac{1}{2}$ degrees of hardness, and it contains large quantities of oxygen in solution ; sometimes the water flows from the tap like aerated or milky water. This is due to the air, which by the great pressure is mingled with the water, and escapes when drawn off. Water under such conditions of pressure and excess of oxygen, would readily form an oxide of lead, which is soluble to the extent of 10 grs. per gallon. The water is also slightly acid. The Sheffield water is freely acid, and DR. WHITE believes it is due to ulmic and humic acids. We know that vegetable acids have considerable solvent action on lead. The acidity of the Bacup water is not due to carbonic acid, and I believe we may exclude ulmic and humic acids, because it is present in the winter months as well as the summer. If due to ulmic acid, it would possibly be absent in the winter. It has been a problem of considerable interest to prove what the acid is. On evaporating a quantity of water to $\frac{1}{10}$ of its bulk, and testing, I found chloride of barium gave a white precipitate, which on heating with HNO_3 or HCl , was insoluble. The concentrated water also charred paper when heated. These two tests are strongly in favour of the acidity of the water being due to the presence of free H_2SO_4 . Lead sulphate is soluble in water to the amount of 2 grs. per gallon. The Bacup water also contains iron in solution, which is derived from the iron pyrites in the shale. It is probable that the iron pyrites is oxidised, and the sulphur combines with oxygen forming free sulphuric acid. The following physical conditions would also assist the solvent action of the water :—(1) The pressure of the water in the lead service pipes. The reservoir is at a considerable elevation ; water acts readily under increased pressure. (2) Friction and pressure on the inner surface of lead pipes when the water is drawn off. (3) Solids in suspension. The water is not filtered, and a quantity of fine sand passes into the pipes, and must increase the action of the water in its flow. (4) Any condition of the lead pipes which obstructs its flow, such as acute angles and

bending the pipes against the grain, by which the water acts more readily.

How to detect
where long
Lead Pipes
may be found.

It is important to make a quantitative analysis of water, by taking a sample from the tap in the morning. If 1 gr. per gallon and upwards be detected, it will be found that there are from 50 feet and upwards of lead piping. By this method I found that several streets had lead mains, and, to my surprise, that my own house had a lead pipe of 100 feet. These streets were attended to. I would suggest that this test should be tried, and have no doubt many cases where long service pipes exist will be detected.

Nature of
Lead in the
Water.

It is probable that the lead existed in two forms in the Bacup water, viz: (1) in solution, and (2) in suspension. Water containing $1\frac{1}{2}$ gr. of lead per gallon was passed through ordinary filtering paper, and 50 per cent. of the lead was removed. The molecules of lead, it would appear, are arrested in the fine pores of the filtering paper. Water with $1\frac{1}{2}$ gr. of lead per gallon was passed through a compressed carbon filter, and all the lead was removed. In only one instance have I detected lead after the water had been filtered through a carbon filter. In this case the filter was home made, and was faulty in construction. The fact that filtering removed the lead led me to make further observations, from which the following significant fact was elicited:—That it was exceptional for any severe case of plumbism to occur where filters were used, whilst it was among those who had no filters that nearly every case of lead paralysis, saturnine rheumatism, saturnine gout, convulsions, &c., occurred.

How to
prevent Con-
tamination of
Water by Lead.

To prevent contamination, use as little lead pipe as possible, run off the water that has been in contact with the lead pipes for any length of time. Use substitutes for lead pipes, such as iron pipes—cast iron is preferable to wrought—glazed earthenware pipes, glass-lined pipes; the latter are perfectly safe, and are not costly; $\frac{1}{2}$ in. bore cost

6d. per foot. Solid blocked tin is good, but rather costly. Tin-cased lead pipe is like the solid blocked tin, but the casing of tin is thinner. It costs about double ordinary lead pipe. Tinned, or tin-washed lead pipes, are *more dangerous* than ordinary lead pipe. Lead pipe made from the virgin ore is far safer than tinned-lead pipe, or lead pipes made from mixed lead. This is made from old lead, and contains zinc, tin, and other metals. The pipe is much harder than virgin ore lead pipes, but, owing to metallic impurities, it is more readily acted upon by water, especially if any free acid is present, as galvanic action is set up. Avoid lead cisterns; use slate cisterns, or galvanised iron; use no red lead for the joints, as it is soluble, and has proved a source of contamination of water with lead. Iron cisterns should be coated with resin or tar, dissolved in benzine, which would protect the iron as well as the red-lead paint, ordinarily used. Iron cisterns painted with lead have caused lead poisoning through the water being contaminated.

We may act on the water so as to prevent its action on lead service pipes; (1) by passing it over a large bed of limestone; (2) also if water contains a free acid like Bacup and Sheffield water, by neutralizing it with carbonate of soda. The latter would be an easy, cheap, and, I believe, effective method. It would have the effect of forming a carbonate of lead on the pipes. No objection can be taken to it on the ground of being injurious to health, or being more costly for domestic use. (3) Another plan would be to make borings down to the abundant underground reservoirs which exist in Bacup in the millstone grit, and mix this with the water collected from the moors, or to use it alone; this would make the water harder, and neutralize, to a certain extent, its action on lead. Some writers state that hard water never acts on lead; this is not absolutely true, as I found water with fifteen degrees hardness dissolve $\frac{1}{2}$ gr. of lead per gallon. Several members of the family had the pathognomonic blue line on the gums. Slacked lime was placed in wells, and the

water passed through before entering the reservoir. The hardness of the water was increased by 2° . It would also improve the water if there were efficient filtering beds; the solids would be removed, and thus the mechanical effect of sand, &c., on the lead pipes be prevented. Every house should have a good filter: that generally used in Bacup is the compressed carbon filter, which removes lead.

Cheap
Filter.

As the worst cases of plumbism occurred where, from poverty, there were no domestic filters, I carried out several experiments on the best way to make an efficient filter: carbon blocks, wood charcoal and sand-stone being used. I found on filtering lead polluted water through a large flower pot, half filled with sand-rock, fine gravel, and sand, that the lead was removed from the water as perfectly and 5 times more rapidly than by any carbon filters. Sandstone may be had for fetching, and some of the poor have now home-made filters of this description.

Results of
Experi-
ments.

1. Water was taken from the Rossendale Waterworks Reservoir and was found free from lead, then placed in a tinned pipe for ten days; when tested it gave $\frac{1}{2}$ gr. of lead per gallon.

2. Same water was kept ten days in lead pipe made from virgin-ore, and it only dissolved $\frac{1}{10}$ gr. of lead per gallon. The practical bearing of this is evident, that virgin-ore lead pipe is much safer than tinned lead pipe. There can be no doubt but that a galvanic action is caused by the *tin-wash*.

3. I added a teaspoonful of carbonate of soda to half a gallon of water which was taken from a lead cistern, it contained over a grain of lead per gallon.

RESULT.—When tested, all the lead was removed. At the bottom of the vessel was a white deposit, which was lead, probably the carbonate, thrown down by the carbonate of soda.

4. Water as No. 3 was placed in a glass vessel in which I placed iron or steel filings, nearly all the lead was removed, but the water dissolved so much iron that it was not fit for dietetic purposes.

An easy and fairly reliable test to be used by medical men in general practise, is the sulphide of ammonium ; precautions should be taken, however, to exclude the presence of iron, which metal may be present, either in a natural state, or as an impurity, caused by iron pipes and cisterns. Two samples of water taken from springs in this neighbourhood were stated to contain lead by two analysts. In my opinion both were led into error by not excluding the presence of iron, which I have found in several springs and wells in this district ; especially one which nearly led me into a similar mistake. In this case the water was derived from a shallow well, sunk in the ground, above the middle or upper series of the Haslingden flags, locally called the second grit of the millstone series. On analysis of this water, I found it to contain over 20 grs. of iron per gallon, which is five times as strong as the Harrogate chalybeate spring. It was also beautifully clear and sparkling. I am not aware that lead is contained in a natural state in any water supply in England.

Hints on
testing
for Lead.

Nascent sulphuretted hydrogen is the more reliable test, and in cases of doubt should always be used.

The method usually adopted is on the principle of NESSLERS test for ammonia. A standard solution of the acetate of lead is prepared, containing 1 m.g. in 1 c.c. A better method I believe to be the following, viz : to substitute chloride for the acetate, of which 1 c.c. of the solution contains 1 m.g. of lead. The objection to the acetate is that it is unstable, and requires to be freshly prepared every few months, whilst the chloride is more stable. A solution of the latter, prepared over 12 months since, remains perfectly clear and reliable.

Quantitative
Analysis.


Recently there have been severe outbreaks of plumbism, due to water contamination from lead service pipes at Sheffield, Bradford, Rochdale, Huddersfield, Keighley, Darwen, Padiham, Pudsey, Norden, Littleborough, Smallbridge, Whitworth, and other places. The extent of the epidemic, the amount of

Public
Investigation
needed.

sickness, and number of deaths, if investigated by a Commission appointed by the Local Government Board, would be simply astounding ; and I am confident that measures would be taken to prevent these recurring outbreaks of plumbism. Some steps ought to be taken to call the earnest attention of the Government to the advisability of appointing a Commission of inquiry.

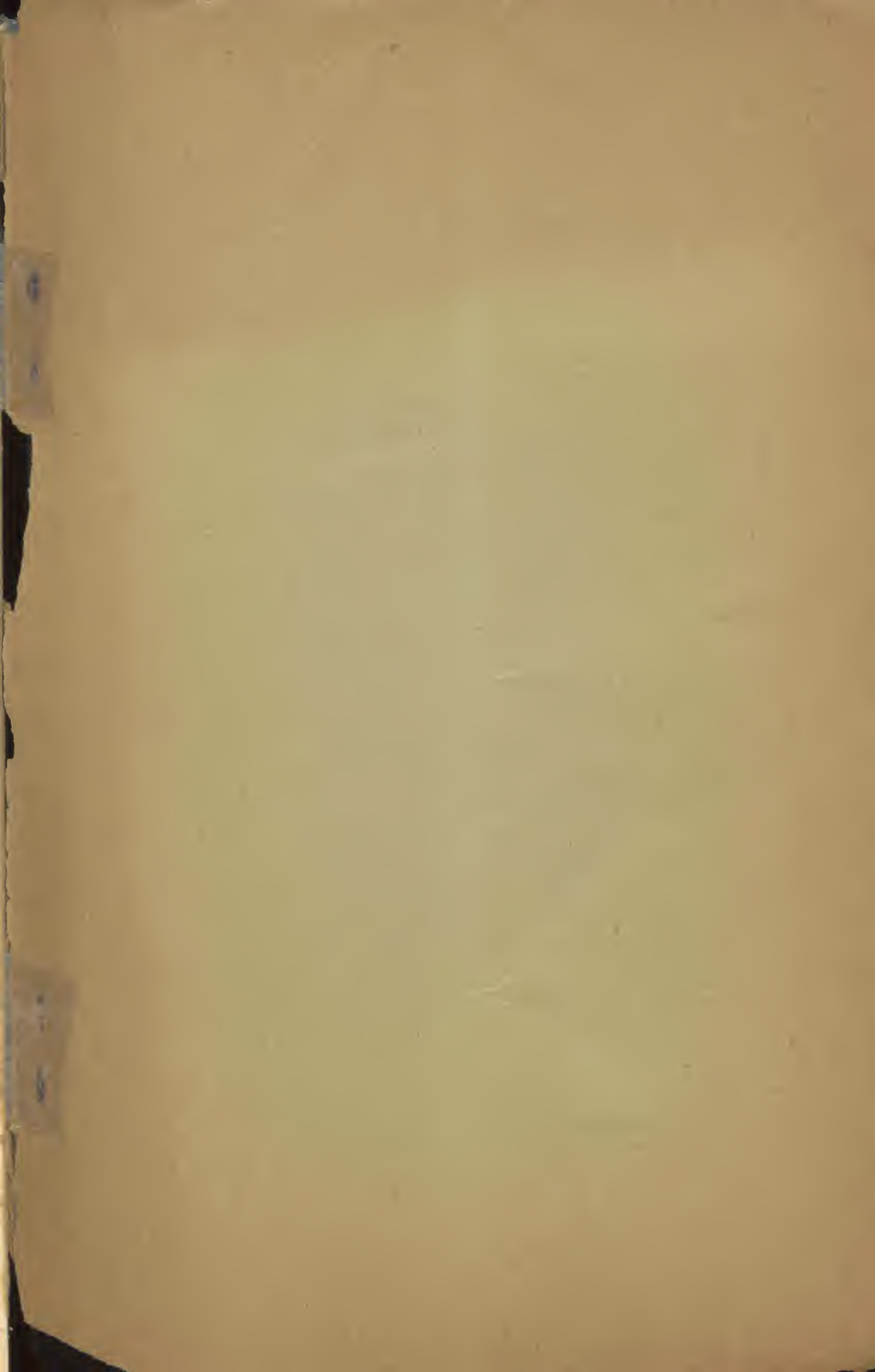


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